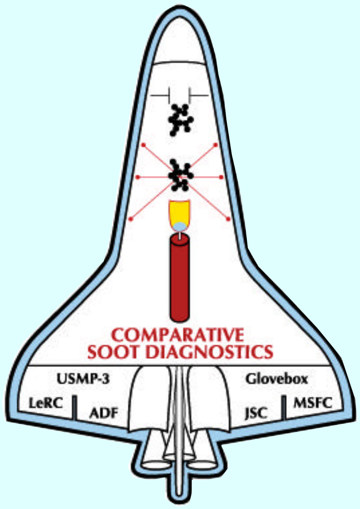


COMPARATIVE SOOT DIAGNOSTICS

(CSD)

Combustion Experiment

There is no fire without some smoke.

John Heywood, writer
Proverbs, 1546

INTRODUCTION

The **Comparative Soot Diagnostics** (CSD) experiment measured the amount and size of soot and smoke particles formed in microgravity.

This experiment provided information for the implementation of fire detectors for the Space Shuttle and the International Space Station, as well as the design of future detectors for spacecraft. In addition, this experiment expanded the knowledge of soot and will help scientists predict the way fire behaves on Earth.

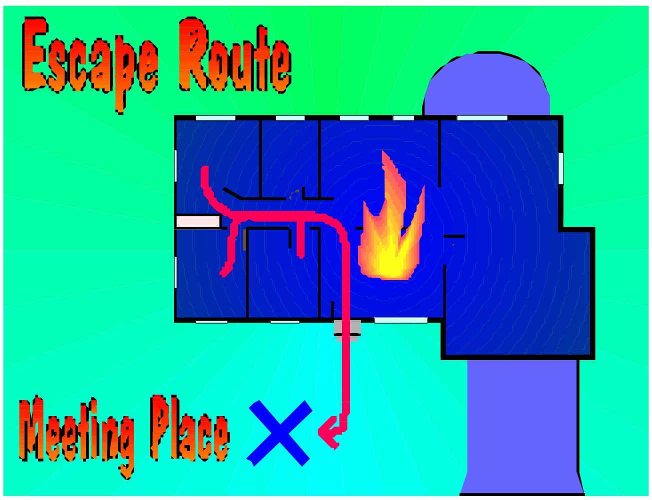
This experiment was conducted aboard the Space Shuttle *Columbia* during flight STS-75 of the third United States Microgravity Payload (USMP-3) mission.

For information about similar experiments, see the Forced Flow Flame Spreading Test (FFFT) and the Radiative Ignition and Transition to Spread Investigation (RITSI) which were also conducted aboard this flight. Also see the Candle Flames in Microgravity (CFM-1), the Smoldering Combustion in Microgravity (SCM), and the Wire Insulation Flammability experiments which were conducted aboard the Space Shuttle *Columbia* during flight STS-50 of the USML-1 mission. Also see the second CFM and FFFT experiments which were conducted aboard the Russian Space Station during the *Mir* Increment 2 mission. Also see the Opposed Flow Flame Spread (OFFS) experiment which was conducted aboard the Russian Space Station during the *Mir* Increment 4 mission.

THE SCIENCE

You're familiar with fire drills. The alarm sounds, everyone leaves by designated exits and gathers a safe distance from the building to wait for the Fire Department. On a good day, everyone enjoys a break and returns to the building safe and sound.

If a fire occurs aboard the Space Shuttle, however, astronauts cannot step outside and telephone the fire department. During space flight, there aren't any escape routes or designated exits.



You may think the solution is simple: install smoke alarms. However, one problem remains.

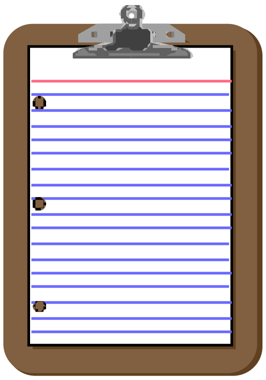
On Earth, flaming fires produce small particles of soot while smoldering fires produce larger soot particles. Gravity causes the soot and smoke to rise. The smoke alarm sounds when the smoke and soot reach the sensors.

In space, without gravity, smoke does not rise. What's more, flames in space do not produce the same amount of soot and smoke as flames on Earth. The smoke detectors depend upon the ventilation system to deliver the smoke to the detector. Depending upon how well the air in a piece of equipment communicates with the cabin air, a smoldering fire could burn for several hours before the astronauts noticed.

This experiment tested fire detection systems for the Space Shuttle and the International Space Station. Using smoke detectors designed for each spacecraft, the experiment tested different materials found in spacecraft crew cabins.

Special sensing devices recorded the amount and size of the soot and smoke particles produced.

The Objectives

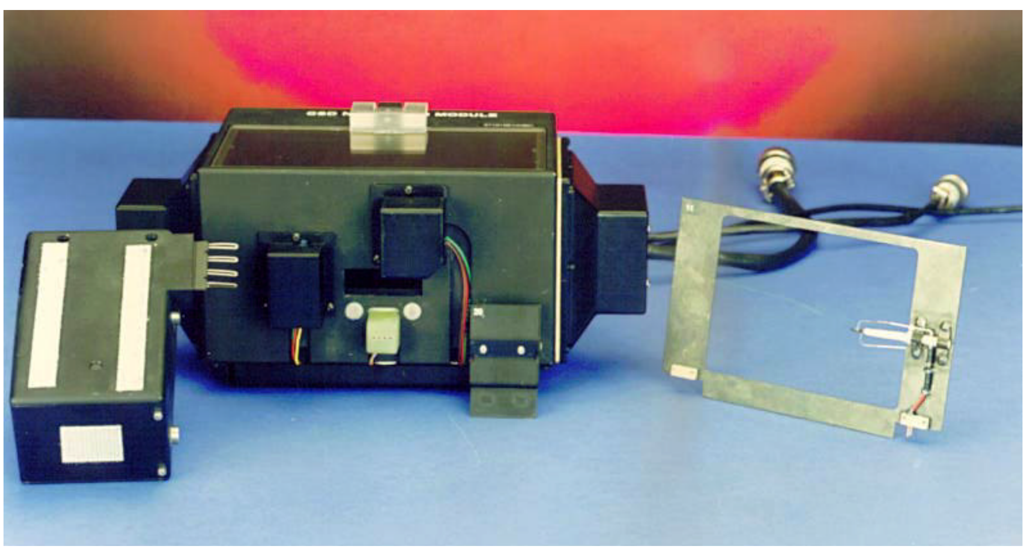


- To measure the size of soot particles produced by a co-flow ventilated candle.
- To measure the size of smoke particles produced by four different materials found aboard a spacecraft.
- To observe the response of smoke detectors to the candles and materials.
- To evaluate the performance of several sensing devices for determining the size and amount of soot and smoke formed by combustion in microgravity.

The Hardware

The hardware consisted of the Near-Field Module and the Far-Field Box.

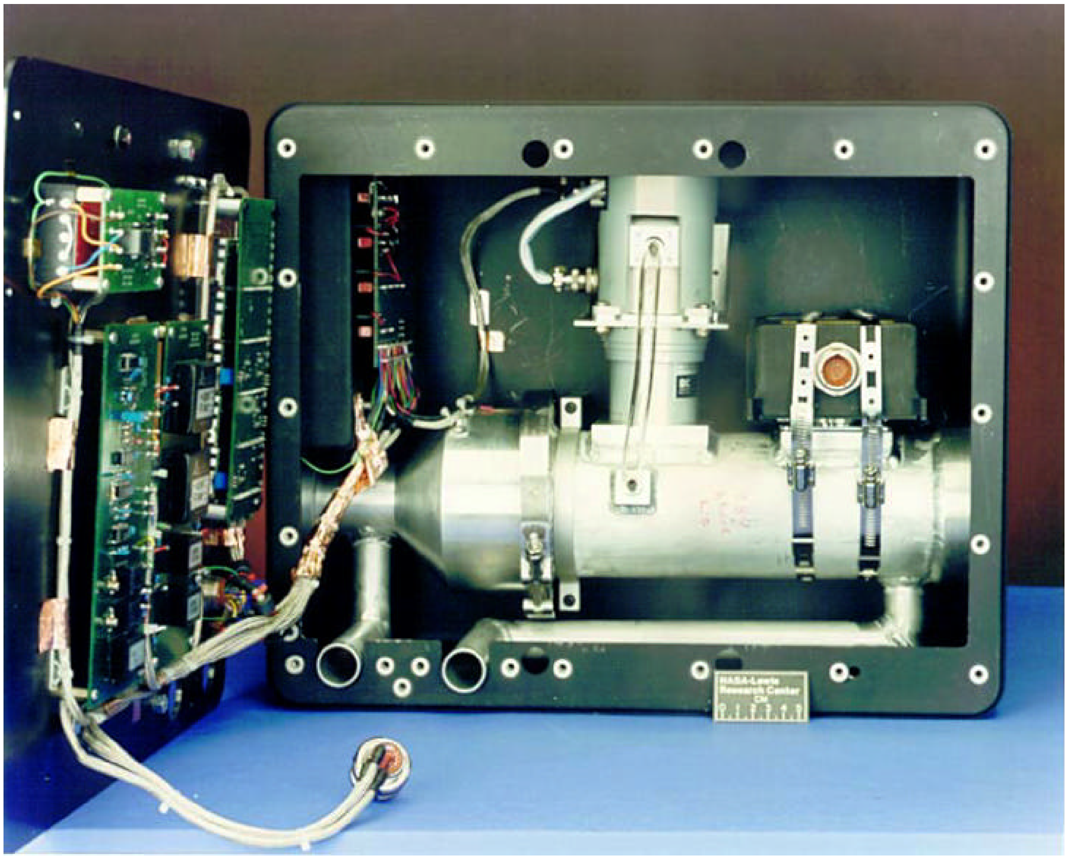
The Near-Field Module was placed inside the Glovebox and contained test samples and sensing equipment.



Near Field Module. On the right, a sample card and candle.

The Far-Field Box was placed outside the Glovebox and contained two smoke detectors.

The smoke detector used in the Space Shuttle (STS) worked the same as most home smoke detectors -- by ionization. The smoke detector planned for the International Space Station (ISS) worked by sensing scattered light.



Far Field Box with Space Shuttle (STS) and International Space Station (ISS) smoke detectors.

A hot-wire ignited the samples. Teflon hoses carried soot and smoke from the near-field tests to the Far-Field Box and back to the Glovebox.

Video cameras recorded each step of the experiment. Special sensing probes recorded the amount and size of the soot or smoke.

THE EXPERIMENT

Commander Andrew Allen and Payload Commander Franklin Chang-Diaz conducted the experiment.

After setting up the equipment in the Glovebox and positioning the video camera, the astronaut ran a series of self-diagnostic procedures on the smoke detectors. Then, he switched on the igniter for a specific length of time (15 to 60 seconds) and started the soot samples. The length of each combustion was about two minutes.

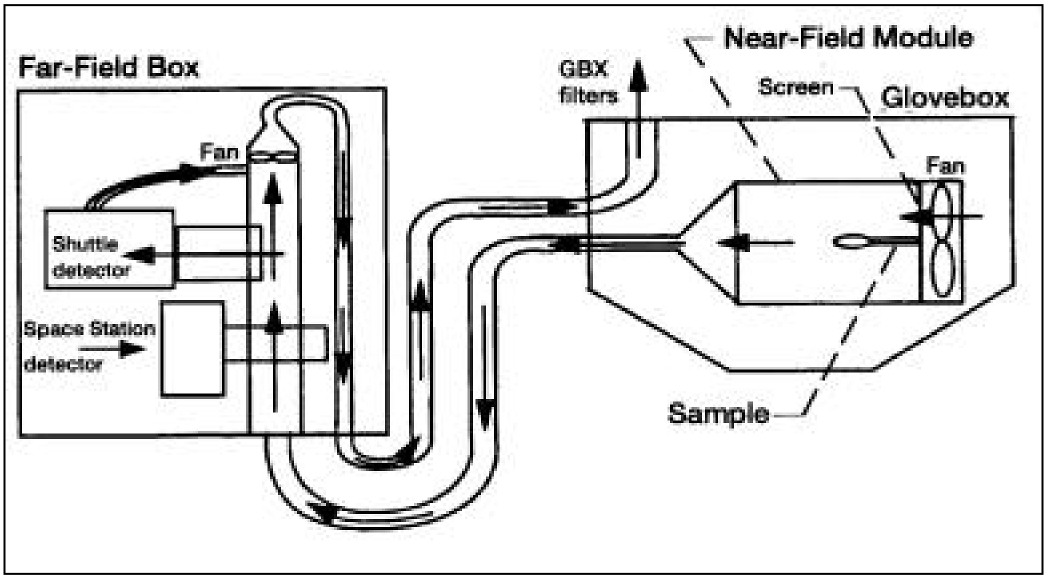


Diagram of the CSD system.

In a series of experiments, candles were tested at four co-flow air velocities, which simulated buoyant air flows.

In a different series of experiments, four materials were tested at four heating rates. The materials were paper, silicone rubber, and wires insulated with Teflon and Kapton.

In each series, special sensing probes recorded the amount and size of the soot and smoke particles. Video cameras recorded the response of the smoke detectors.

The Results

The experiment was designed to produce enough particles to measure the sensitivity of both smoke detectors. In twenty-five tests, smoke and soot particles were collected on grids.

Different materials were selected to produce different types of smoke. For example, the paper and silicone rubber samples produce smoke containing liquid droplets. The plastics and candles produce solid smoke particles.

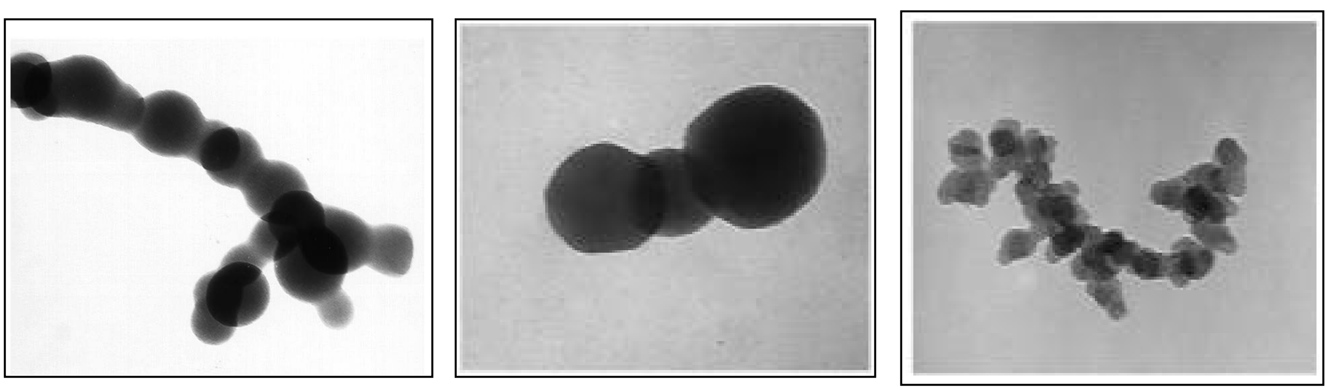
For the candle tests, both smoke detectors responded as soon as the candle was ignited. The Shuttle detector had strong signals for all the tests. The Space Station detector had varied signals. The cause is being studied.

For the paper tests, the Space Station detector showed strong signals, while the Shuttle detector had limited signals.

For the silicone rubber test, the Space Station detector showed very strong signals. The Shuttle detector showed a weak signal.

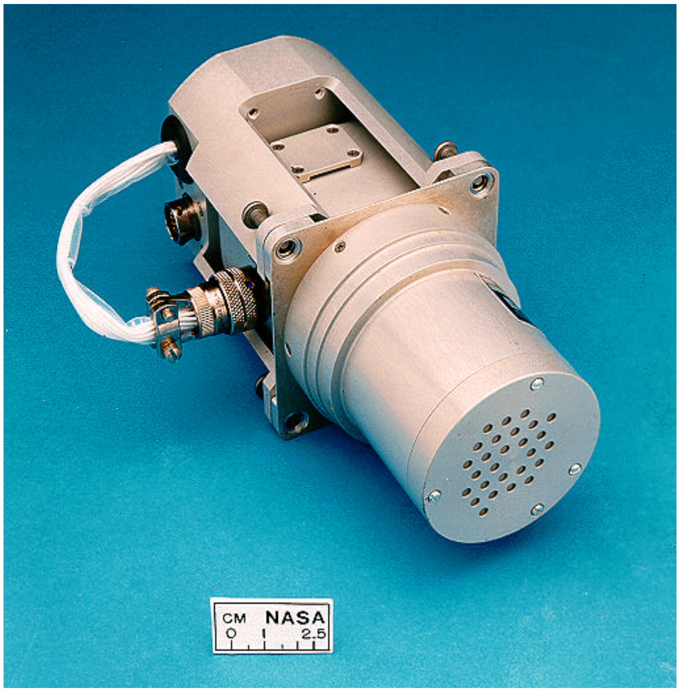
Both the silicone rubber and paper produced thick and clearly visible smoke.

For the Teflon and Kapton wire tests, both detectors' signals varied from strong to weak, consistent with the sample heating rate (smoke emission rate) for each test.



Left to right: smoke particles from overheated Teflon, Kapton, and candles.

THE CONCLUSIONS



The Space Shuttle (STS) smoke detector.

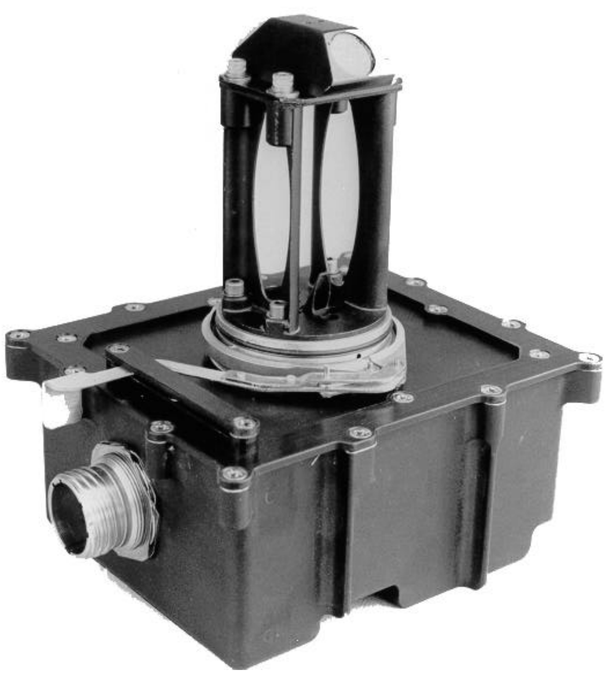
In general, each smoke detector had different characteristics.

While scientists are still studying the information, at this point, the most important conclusion involves smoke sensitivity.

Sensitivity to the smoke from a material burning in normal gravity does not mean sensitivity to the smoke from the same material burning in microgravity.

The Space Shuttle detector was sensitive to small particles but not large particles.

The Space Station detector was sensitive to large particles.



The International Space Station (ISS) smoke detector.

Benefit to Quality of Life on Earth

Information about the formation of soot and smoke in microgravity can be applied to a wide variety of Earth-bound systems.

From an environmental standpoint, bright, sooty fires are necessary for efficient energy production in furnaces and power equipment. Information about soot formation may increase this efficiency. On the other hand, we know soot from trucks, buses, and jet engines pollutes the environment. If scientists can reduce the amount of soot particles released into the environment, humans may breathe cleaner, healthier air.

From an economic standpoint, soot is one of the most important industrial by-products of combustion. In certain cases, soot affects the durability and performance of combustion equipment. Manufacturing industries that depend on flames such as the steel and automobile companies may create better, more cost-effective processes.

Finally, soot is an important product used in paint, tires, and most commercial products containing black pigment.

Future Work

Space flights are becoming longer, more complicated, and more frequent. As a result, effective fire detection systems are necessary to protect the lives of astronauts. Prior to the Comparative Soot Diagnostics experiment, microgravity information about soot and smoke were limited to the results from short fires conducted in drop towers. This test provided the first measurements of longer burning flames.

Further experiments will expand this information and help scientists test and design reliable spacecraft smoke detection systems.

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